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Evaluation of heavy metals in different fish samples from different water sources in Odisha: Animal and human health risk assessment

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Abstract

Different chemical contaminants are released into water bodies which include radionuclides, Phthalates, aliphatic and aromatic chemicals, also heavy metals. They cause unintended changes in physiological and biological components of the ecosystem which ultimately disrupts the balance of ecology and affect people directly or indirectly. So we planned to assess the concentrations of Zinc, Mercury, Iron, Copper & Chromium in different fish samples (In liver and muscle). Total 36 fishes of 5 different species were collected from Mahanadi River, Puri sea, and Chilika lake water bodies. Fishes were procured from local fish markets at local places. *Labeo rohita*, *Cirrhinus cirrhosis*, Bhakti, Pomfret, Tuna fish species were selected for assessment because these are the major fishes consumed by people. By using ICP-OES instrument levels of metal concentrations were measured. Amongst all fish species, more metals found accumulated in *Cirrhinus cirrhosis* (Mrigal) followed by *Labeo rohita* procured from Mundali village market. In comparison to the muscle sample, the liver sample had a higher concentration of metals. The average and range of metals concentrations found in the liver sample of Mahanadi river fish were (in mg/L): Cr (0.78), Cu (17.28), Fe (58.71), Zn (19.30), Hg (0.20). In Puri sea fishes it was Cr (0.67), Cu (15.18), Fe (55.44), Zn (17.48), Hg (0.13). In Chilika lake fishes, Cr (0.58), Cu (14.52), Fe (50.23), Zn (12.66), Hg (0.13) were found. Statistically Significant difference of amount of metals were observed in Mahanadi River, Puri sea and Chilika locations.

The average and range of different metals concentration found in a muscle sample of Mahanadi river fish were in mg/L: Cr (0.25), Cu (4.95), Fe (20.20), Zn (7.03), Hg (0.08). In Puri sea fish it were Cr (0.14), Cu (3.99), Fe (18.29), Zn (6.89), Hg (0.05). There was statistically significant difference in amounts of metals observed in fishes of Mahanadi River, Puri Sea and Chilika Lake. The metal concentrations found in edible parts of fish samples were below the maximum level set by WHO, FAO, USEPA and USFDA. So the fishes of these locations are safe for human consumption.

Keywords: Heavy metals, fish, Mahanadi, Puri sea, Chilika, consumption

Introduction

Fish contains all necessary amino acids and in comparison to red meat, has low fat content. Fish also contains Omega-3 fatty acids EPA (Eicosapentaenoic acid) & DHA (Docosahexaenoic acid). In eastern India, traditionally fish is a regular part of diet of pregnant women believed to be helpful in cerebellar and brain growth of the foetus. (Basak *et al.*, 2020) ^[1]. Effluents released into different water body cause unintended changes of the ecosystem causing imbalance in environment and affect people directly or indirectly.

The accumulation of metals in food and their impact on people is a global concern. In various circumstances metal pollution of water bodies pose serious concerns. Aquatic creatures are the first to suffer. Heavy metals enter into the food chain and harm other animals depending on bioaccumulation and bio magnifications. Ample amount of fatty acids, proteins, carbs, vitamins, minerals and essential amino acids are found in fish. Fish is one of the major sea food, so accumulated heavy metals in fish is transferred to humans. (Raja *et al.*, 2009) ^[10]. A diverse group of fishes known as freshwater fish inhabit water bodies where salinity is less than 1.05%. The muscle protein of fish is highly valuable because it has essential amino acids lysine and threonine which are crucial for protein synthesis and other functions in humans. Major non-protein nitrogenous compounds found are proline, glutamine, glycine, alanine, and arginine and taurine. Taurine is important for bile salts. Taurine alone or with LC-PUFA reduce the risk of coronary heart diseases (James, 2013) ^[5].

To manage women's various health conditions, fish oil is used such as to relief in painful periods and breast pain. (Phang *et al.*, 2005) ^[14] Contaminated by various drugs/chemicals freshwater ecosystem, fish accumulate harmful chemicals which ultimately harm the other animals and people who consume them.

Materials and Methods

Selection of fish species

Commonly consumable and highly demanded fish species were selected for this current study work. *Labeo rohita* (Rohu), *Cirrhinus cirrhosus* (Mrigal), Tuna (*Thunnini*) fish, Bhetki (*Lates calcarifer*) and Pomfret (*Pampus argenteus*) fish were selected for further study work. *Labeorohita* (Rohu) and *Cirrhinus cirrhosus* (Mrigal) collected from Mahanadi River. Bhetki and Pomfret fish collected from local market of Puri. Tuna and Rohu fish collected from local market of Chilika. Both production and consumption of Rohu, Mrigal and Tuna as regular fish meals on different occasions or ceremonies is more than other finfish and shellfish species. Therefore, these species consumed the maximum population of Odisha.

Markets selection for sampling

Commonly consumed fish species were purchased from the local fish market of Chilika, Puri and Mundali villages. In Odisha, there is a brackish water lagoon known as Chilika Lake that spans the districts of Puri, Khurda, and Ganjam. Different fish species were collected from different water sources, *i.e.*, Chikika Lake, Puri Sea and Mahanadi River. Puri sea contains salty water, Mahanadi River contain fresh water.

Sample digestion

- One gm of sample was taken for a determination of different metals concentration.
- One gm of dried powder sample taken into a volumetric

flask into which 70% of 6 ml Nitrous oxide (HNO₃) and 30% of 4 ml Hydrogen peroxide (H₂O₂) were added. Then volumetric flask was kept on the hot plate for digestion.

- Hot plate temperature was adjusted to 210 °C for the digestion of the fish sample. The sample was heated until the color changed from brownish yellow into transparent yellow to transparent. The sample was heated for complete digestion.
- After that sample was taken from the hot plate and kept to be cooled Measured 25 ml of ultra-pure water by using ameasuring cylinder.
- Then the sample was poured into another empty volumetric flask and then 25 ml of ultra-pure water was added. Ultra-pure water makes a solution diluted. Whatmann filter paper no. 41 was used for the filtration of the solution.
- Then it was analyzed for the presence of heavy metals by using Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES) available at the central instrumentation Facility, OUAT.

The following metals were estimated from the collected tissue samples (Liver, Muscle):

- Copper
- Chromium
- Mercury
- Iron
- Zinc

Results

In the current study, the metal accumulation pattern exhibited the following order: Fe > Zn > Cu > Cr > Hg.

The location-wise difference in metals accumulation in fish liver samples: Among 3 locations metals accumulation was higher in Mahanadi River and lower in Chilika Lake.

Table 2: Mean concentration of different metal sin the liver of different fish samples from different regions of Odisha (n = 12)

Metals	Maximum permissible limit (ppm)	Location			f-value
		Mahanadi	Puri	Chilika	
Cr (mg/L)	1	0.78 ^a ± 0.01	0.67 ^b ± 0.03	0.58 ^c ± 0.01	25.88**
Cu (mg/L)	30	17.28 ^a ± 0.18	15.18 ^b ± 0.19	14.52 ^c ± 0.18	63.45**
Fe (mg/L)	100	58.71 ^a ± 1.02	55.44 ^b ± 1.45	50.23 ^c ± 0.38	16.66**
Zn (mg/L)	30	19.30 ^a ± 0.17	17.48 ^b ± 0.16	12.66 ^c ± 0.14	485.61**
Hg (mg/L)	0.5	0.20 ^a ± 0.01	0.13 ^b ± 0.01	0.13 ^b ± 0.00	61.51**

Means with different super scripts indicate significant differences at the **p* < 0.05 and ***p* < 0.01 levels

Table 3: Mean concentration of different metals in the muscle of different fish species from a different region of Odisha (n = 12)

Metals	Maximum permissible limit (ppm)	Location			f-value
		Mahanadi	Puri	Chilika	
Cr (mg/L)	1	0.25 ^a ± 0.01	0.14 ^b ± 0.01	0.09 ^c ± 0.01	44.18*
Cu (mg/L)	30	4.95 ^a ± 0.14	3.99 ^b ± 0.15	4.11 ^c ± 0.11	14.78**
Fe (mg/L)	100	20.20 ^a ± 0.51	18.29 ^b ± 0.20	16.02 ^c ± 0.43	27.49**
Zn (mg/L)	30	7.03 ^a ± 0.70	6.89 ^b ± 0.35	6.14 ^b ± 0.79	6.70**
Hg (mg/L)	0.5	0.08 ^a ± 0.02	0.05 ^b ± 0.02	0.05 ^c ± 0.01	10.17**

Means with different super scripts indicate significant differences at the **p* < 0.05 and ***p* < 0.01 levels

Table 4: Accumulation of metals concentration in different fish species (n = 12)

Metals	Fish species			Pomfret	Tuna	f-value
	Rohu (n = 24)	Mrigal	Bhetki			
Cr (mg/L)	0.66 ^a ± 0.03	0.80 ^b ± 0.02	0.70 ^a ± 0.04	0.65 ^a ± 0.04	0.59 ^c ± 0.02	4.61*
Cu (mg/L)	15.79 ^a ± 0.42	17.45 ^b ± 0.31	15.38 ^a ± 0.22	14.97 ^a ± 0.29	14.55 ^c ± 0.27	7.19**
Fe (mg/L)	55.04 ^a ± 1.60	57.53 ^a ± 1.57	56.12 ^a ± 2.14	54.76 ^a ± 2.13	50.27 ^b ± 0.53	1.10
Zn (mg/L)	15.83 ^a ± 1.01	19.47 ^b ± 0.25	17.70 ^b ± 0.23	17.27 ^b ± 0.19	12.80 ^c ± 0.21	8.44**
Hg (mg/L)	0.16 ^a ± 0.01	0.20 ^b ± 0.01	0.13 ^c ± 0.01	0.13 ^c ± 0.01	0.13 ^c ± 0.00	6.80**

Means with different super script differ significantly at * $p < 0.05$, ** $p < 0.01$

Table 5: Two-way Anova between metals concentration (Cr, Cu, Fe, Zn, Hg) found in liver samples collected from Mahanadi River fish (Rohu, Mrigal) and Puri fish (Bhetki, Pomfret)

Source of variation	SS	Df	MS	F	p-value	Fcrit
Sample	40.55	1	40.54	12.42	0.0005	3.91
Columns	57281.66	5	11456.33	3510.7	1.68E-138	2.28
Interaction	75.96	5	15.19	4.65	0.0006	2.28
Within	430.74	132	3.26			

Above table indicate that there was a statistically significant difference observed in different metals concentration (Cr, Cu, Fe, Zn, Hg) found in liver of Mahanadi and Puri fish samples. “P” value observed was < 0.01 .

Table 6: Two-way Anova between metals concentration (Cr, Cu, Fe, Zn, Hg) found in liver samples collected from Mahanadi River fish (Rohu, Mrigal) and Chilika fish (Rohu, Tuna)

Source of variation	SS	Df	MS	F	p-value	Fcrit
Sample	261.09	1	261.09	202.06	2.2E-28	3.91
Columns	51692.17	5	10338.43	8001.10	5.5E-162	2.28
Interaction	505.14	5	101.03	78.19	9.4E-38	2.28
Within	170.56	132	1.29			

Above table indicate that there was a statistically significant difference observed in different metals concentration (Cr, Cu, Fe, Zn, Hg) found in liver of Mahanadi and Chilika fish samples. “P” value observed was < 0.01 .

Table 7: Two-way Anova between metals concentration (Cr, Cu, Fe, Zn, Hg) found in liver samples collected from Puri fish (Bhetki, Pomfret) and Chilika fish (Rohu, Tuna)

Source of variation	SS	Df	MS	F	P-value	Fcrit
Sample	95.86	1	95.86	40.40	3.1E-09	3.91
Columns	48314.17	5	9662.83	4072.11	1.0E-142	2.28
Interaction	215.44	5	43.09	18.16	1.1E-13	2.28
Within	313.23	132	2.37			

Above table indicate that there was a statistically significant difference observed in different metals concentration (Cr, Cu, Fe, Zn, Hg) found in liver of Mahanadi and Chilika fish samples. “P” value observed was < 0.01 .

Table 7: Two-way Anova between metals concentration (Cr, Cu, Fe, Zn, Hg) found in liver samples collected from Puri fish (Bhetki, Pomfret) and Chilika fish (Rohu, Tuna)

Source of variation	SS	Df	MS	F	P-value	Fcrit
Sample	95.86	1	95.86	40.40	3.1E-09	3.91
Columns	48314.17	5	9662.83	4072.11	1.0E-142	2.28
Interaction	215.44	5	43.09	18.16	1.1E-13	2.28
Within	313.23	132	2.37			

Above table indicate that there was a statistically significant difference observed in different metals concentration (Cr,

Cu, Fe, Zn, Hg) found in liver of Puri and Chilika fish samples. P” value observed was < 0.01 .

Table 8: Two-way Anova between metals concentration (Cr, Cu, Fe, Zn, Hg) found in muscle samples collected from Mahanadi River fish (Rohu, Mrigal) and Puri fish (Bhetki, Pomfret)

Source of variation	SS	Df	MS	F	p-value	Fcrit
Sample	4.56	1	4.56	11.72	0.0008	3.91
Columns	6380.10	5	1276.02	3276.95	1.54E-136	2.28
Interaction	28.98	5	5.80	14.88	1.43E-11	2.28
Within	51.40	132	0.39			

Above table indicate that there was a statistically significant difference observed in different metals concentration (Cr, Cu, Fe, Zn, Hg) found in muscle of Mahanadi and Puri fish samples. “P” value observed was < 0.01 .

Table 9: Two-way Anova between metals concentration (Cr, Cu, Fe, Zn, Hg) found in muscle samples collected from Mahanadi River fish (Rohu, Mrigal) and Chilika Fish (Rohu, Tuna)

Source of variation	SS	Df	MS	F	p-value	Fcrit
Sample	16.72	1	16.72	29.54	2.55E-07	3.91
Columns	5542.26	5	1108.45	1958.15	6.15E-122	2.28
Interaction	121.42	5	24.28	42.90	4.45E-26	2.28
Within	74.72	132	0.57			

Above table indicate that there was a statistically significant difference observed in different metals concentration (Cr, Cu, Fe, Zn, Hg) muscle of Mahanadi and Chilika fish samples. “P” value observed was < 0.01 .

Table 10: Two-way Anova between metals concentration (Cr, Cu, Fe, Zn, Hg) found in muscle samples collected from Puri fish (Bhetki, Pomfret) and Chilika fish (Tuna, Rohu)

Source of variation	SS	Df	MS	F	P-value	Fcrit
Sample	3.82	1	3.82	11.96	0.00073304	3.91
Columns	4931.78	5	986.36	3091.15	7.02E-135	2.28
Interaction	36.69	5	7.34	23.00	1.49E-16	2.28
Within	42.12	132	0.32			

Above table indicate that there was a statistically significant difference observed in different metals concentration (Cr, Cu, Fe, Zn, Hg) muscle of Puri and Chilika fish samples. “P” value observed was < 0.01 .

Table 11: Two-way anova between combined fish samples (Rohu, Mrigal, Bhetki, Pomfret, Tuna) collected from different places

Source of variation	SS	Df	MS	F	P-value	Fcrit
Sample	300.06	5	60.01	24.95	4.58E-19	2.26
Columns	77902.48	5	15580.50	6478.83	4.25E-201	2.26
Interaction	576.36	25	23.05	9.59	6.72E-22	1.57
Within	432.87	180	2.40			

Above table indicate that there was a statistically significant difference observed in different fish samples (Rohu, Mrigal, Bhetki, Pomfret, Tuna) collected from Mahanadi River, Puri

and Chilika places. Along with that there was also significant difference observed in metals concentration (Cr, Cu, Fe, Zn, Hg). P value observed was < 0.01.

Table 12: Comparison of metals concentration (µg/g) in the present study with other studies

Area	Metals					Authors
	Cr	Cu	Fe	Zn	Hg	
Mahanadi river, chilika, Puri	0.58-0.78	14.52-17.28	50.23-58.71	12.66-19.30	0.13-0.20	Present study
WHO	-	30	100	100	-	WHO (1989)
USFDA	12	-	-	-	-	USFDA (2001)
USEPA	-	-	-	-	0.5	USEPA (2001)
FAO	1	-	-	30	-	FAO (1983)
Mumbai Harbor, India	0.47	2.46	97.04	38.54	0.06	Velusamy <i>et al.</i> , 2014
Mumbai, India	0.31	0.78	-	8.36	0.015	Mishra <i>et al.</i> , 2007 ^[8]
Calicut, India	0.6	2.8	-	6	-	Sankar <i>et al.</i> , 2006 ^[12]
KolleruLake, Kerala, India	19	-	-	80	-	Batvari <i>et al.</i> , 2008

Discussion

The present study aimed to determine the metals Conc. (Cr, Cu, Fe, Zn, Hg) in different fish species. Liver and muscle tissue samples were collected and determine the metals conc. in tissue samples. For the study work, fish species were collected from 3 locations, i.e., Mahanadi River, Puri and Chilika Lake. Fish were purchased from the local fish market. Chilka Fish was more-safer than Puri sea fish and Mahanadi river fish. More metals concentration was accumulated in Mahanadi river fish. More metals accumulated in mrigal fish than other fish species.

In the current study highest metals conc. found in the liver as compared to the muscle which was supported by the liver is a key organ for detoxification, and it is where many harmful substances acquired from the environment are cleaned up (Fernandes *et al.*, 2008)^[3]. The distribution of metals in fish organs, such as the liver, gills, muscle, and gonads, varies, leading to variances in metal accumulations in these organs (Chi *et al.*, 2007)^[2]. The investigated metals were found in muscle at the lowest amounts, but the liver found to be the principal tissue for accumulating heavy metals. The levels of heavy metals in the muscle were safe for human consumption (Jaric *et al.*, 2011)^[4]. Metals have varying affinities for fish tissue and have different absorption, deposition, and excretion rates, there are variances in the bioaccumulation of metals in fish bodies (Jezierska *et al.*, 2006)^[6].

In the liver, metallothionein binds toxic metals such as Cu and Zn. According to reports, the detoxification, redistribution, and storage of heavy metals are all crucial functions of the fish liver (Weber *et al.*, 2013)^[16].

In the present study, more metals accumulated in *Cirrhinus* spp than in *Labeo rohita* which was similar to the findings of (Rauf *et al.*, 2009)^[11] and also more accumulation in the liver sample as compared to muscle.

In the present study, less metals conc. found in fish muscle samples which were similar to the findings of (Kargin *et al.*, 1991)^[7] muscle tissue is the most crucial component of the fish used in the experiment since it is the part that humans

most frequently ingest and is not thought to be an active site for the buildup of metal.

In the present investigation, the accumulation of metals was in the following order: Fe > Zn > Cu > Cr > Hg which was similar to the findings of (Parida *et al.*, 2017)^[13]. Also similar to the findings of (Velusamy *et al.*, 2014)^[15] important data on the levels of heavy metals in fish from Mumbai Harbor and international markets also found a higher level of Fe present in the fish sample as compared to other metals. A similar order of accumulation of metals was observed in (Prasath *et al.*, 2008)^[9] but in his study, there was a significantly high conc. of iron and zinc found.

In the present study, Hg Conc. found in the range between 0.13-0.20 mg/l and it is found to be lower than the USEPA (2001). These range slightly lower than those (Velusamy *et al.*, 2014)^[15]. Due to industrial waste discharges, mercury (Hg), a very hazardous element, severely pollutes the environment. Fish ingest Hg by feeding, which can be predicted by factors such as fish size, food, ecological factors and water quality factors.

Zinc was the second most abundant metal found in these studies. Zinc Conc. in the present investigation was in the range between 12.66-19.30 in the liver sample which was below the permissible limit of FAO (1983), WHO (1989).

Table 12 indicates that the present study level of Zn was lesser than fish samples of Mumbai Harbor (Velusamy *et al.*, 2014)^[15] but more than the Calicut India Fish samples (Sankar *et al.*, 2006)^[12] & Mumbai, India fish samples (Mishra *et al.*, 2007)^[8].

In the current study, Cu Conc. found in the range between 14.52-17.28 mg/l which found below the permissible level set by (WHO 1989/FAO 1983). Table 12 indicates that the present study level of Cu was somewhat more than in other locations.

In the present study, Cr Conc. found in the range between 0.58-0.78 mg/l which found below the permissible level set by (FAO 1983) and was slightly higher than that (Velusamy *et al.*, 2014, Mishra *et al.*, 2007)^[15, 8].

Conclusion

In this particular study, our focus was on assessing the concentrations of various metals, including iron, zinc, mercury, copper and chromium, in both the muscle and liver tissue of five distinct fish species.

“P” value was observed <0.01 there was a significant difference observed in the accumulation of metals with respect to muscle and liver samples of fish collected from different locations i.e., Mahanadi River, Puri Sea, Chilika Lake.

In the present investigation, the accumulation of metals followed a distinct order: iron (Fe) > zinc (Zn) > copper (Cu) > chromium (Cr) > mercury (Hg). This order highlights the varying concentrations of these metals within the samples analyzed. Throughout all the results, a considerably higher amount of metals was observed in the liver samples compared to the muscle tissue.

Chilka fish was more safer than Puri sea fish and Mahanadi river fish. More metals concentration was accumulated in Mahanadi river fish. More metals accumulated in mrigal fish than other fish species.

In our comprehensive analysis, it was determined that all measured metal concentrations in the fish samples remained below the maximum permissible limits established by reputable regulatory bodies such as the Food and Agriculture Organization (FAO), World Health Organization (WHO), United States Food and Drug Administration (USFDA) and United States Environmental Protection Agency (USEPA). During the investigation higher conc. of Iron was observed in all 3 locations and a lower level of mercury conc. was observed.

We conclude that the edible part of fish is safe for human consumption in a different region that was selected for the study.

References

- Basak S, Mallik R, Duttaroy AK. Maternal docosahexaenoic acid status during pregnancy and its impact on infant neurodevelopment. *Nutrients*. 2020;12(12):3615.
- Chi QQ, Zhu GW, Langdon A. Bioaccumulation of heavy metals in fishes from Taihu Lake, China. *Journal of Environmental Sciences*. 2007;19(12):1500-1504.
- Fernandes C, Fontainhas-Fernandes A, Cabral D, Salgado MA. Heavy metals in water, sediment and tissues of *Liza saliens* from Esmoriz-Paramos lagoon, Portugal. *Environmental Monitoring and Assessment*. 2008;136(1-3):267-275.
- Jarić I, Višnjić-Jeftić Ž, Cvijanović G, Gačić Z, Jovanović L, Skorić S, *et al.* Determination of differential heavy metal and trace element accumulation in liver, gills, intestine and muscle of sterlet (*Acipenser ruthenus*) from the Danube River in Serbia by ICP-OES. *Microchemical Journal*. 2011;98:77-81.
- James D. Risks and benefits of seafood consumption. *Globefish Research Programme*. 2010;108:1-22.
- Jezierska B, Witeska M. The metal uptake and accumulation in fish living in polluted waters. In: *Soil and Water Pollution Monitoring, Protection and Remediation*. Dordrecht: Springer; 2006. p. 107-114.
- Kargin F, Erdem C. Accumulation of copper in liver, spleen, stomach, intestine, gill and muscle of *Cyprinus carpio*. *Turkish Journal of Zoology*. 1991;15:305-314.
- Mishra S, Bhalke S, Saradhi IV, Suseela B, Tripathi RM, Pandit GG, *et al.* Trace metals and organometals in selected marine species and preliminary risk assessment to human beings in Thane Creek area, Mumbai. *Chemosphere*. 2007;69:972-978.
- Prasath PM, Khan TH. Impact of tsunami on the heavy metal accumulation in water, sediments and fish at Poompuhar Coast, southeast coast of India. *Journal of Chemistry*. 2008;5:16-22.
- Raja P, Veerasingam S, Suresh G, Marichamy G, Venkatachalapathy R. Heavy metals concentration in four commercially valuable marine edible fish species from Parangipettai Coast, southeast coast of India. *International Journal of Animal and Veterinary Advances*. 2009;1(1):10-14.
- Rauf A, Javed M, Ubaidullah M. Heavy metal levels in three major carps (*Catla catla*, *Labeo rohita* and *Cirrhina mrigala*) from the River Ravi, Pakistan. *Pakistan Veterinary Journal*. 2009;29:24-26.
- Sankar TV, Zynudheen AA, Anandan R, Viswanathan Nair PG. Distribution of organochlorine pesticides and heavy metal residues in fish and shellfish from Calicut region, Kerala, India. *Chemosphere*. 2006;65:583-590.
- Parida SK, Barik B, Mohanty PR, Muduli SK, Mohanty S, Samanta S, *et al.* Trace metal concentrations in euryhaline fish species from Chilika lagoon: human health risk assessment. *International Journal of Environmental Science and Technology*. 2017;14:2649-2660.
- Phang M, Skilton MR. Marine omega-3 fatty acids, complications of pregnancy and maternal risk factors for offspring cardiometabolic disease. *Marine Drugs*. 2018;16(5):138.
- Velusamy P, Satheesh Kumar P, Ram A, Chinnadurai S. Bioaccumulation of heavy metals in commercially important marine fishes from Mumbai Harbor, India. *Marine Pollution Bulletin*. 2014;81:218-224.
- Weber P, Behr E, Knorr C, Vendruscolo D, Flores E, Dressler V, *et al.* Metals in the water, sediment, and tissues of two fish species from different trophic levels in a subtropical Brazilian river. *Microchemical Journal*. 2013;106:61-66.